Love at first hop? A pilot study on the social behavior of companion rabbits during the introduction period

Liefde bij de eerste hop? Een pilootstudie naar het sociale gedrag van gezelschapskonijnen tijdens de introductieperiode

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ABSTRACT

The pet rabbit (*Oryctolagus cuniculus*), known for its social nature, often experiences sub-optimal living conditions when kept in solitary housing, as it fails to meet its social needs. In this study, the social dynamics during the introduction of companion rabbits are investigated focusing on opposite-sex pairs, and behavioral traits that may be linked to successful pairings are examined (i.e. defined as rabbit pairs living together for at least three months after the introduction). Eight introductions involving 17 rabbits at a shelter were recorded, and the recorded videos were analyzed for behavioral interactions. Key behaviors were quantified based on their presence, frequency and duration. Descriptive statistical analysis revealed that successful pairings were characterized by higher prevalence of approaching, mounting on the head and sniffing the other rabbit. In contrast, aggressive behaviors such as attacking, fighting and threatening were more prevalent in unsuccessful pairings. The findings of the present study underscore the importance of careful pairing and understanding behavioral indicators to improve social housing of rabbits, ultimately enhancing their welfare.

SAMENVATTING

Het gezelschapskonijn wordt vaak individueel gehuisvest zonder soortgenoten, wat tegenstrijdig is met zijn sociale aard. In deze studie werd de sociale dynamiek tussen gezelschapskonijnen van verschillend geslacht tijdens de introductie onderzocht. Het doel was om gedragskenmerken te identificeren die mogelijk voorspellend zijn voor een succesvolle koppeling (voor de studie gedefinieerd als een koppeling die resulteert in konijnen die ten minste drie maanden samenleven na de introductie). Er werden acht introducties met 17 konijnen vastgelegd op beeld in een opvangcentrum, waarna de opgenomen video's geanalyseerd werden op gedragsinteracties. Gedragingen werden gekwantificeerd op basis van hun aanwezigheid, frequentie en duur. De resultaten worden beschrijvend weergegeven en tonen aan dat de succesvolle koppelingen werden gekenmerkt door een hogere prevalentie van benaderen, het berijden van de kop en het besnuffelen van het andere konijn. Onsuccesvolle koppelingen werden eerder gekenmerkt door agressieve gedragingen zoals aanvallen, vechten en bedreigen. Deze bevindingen benadrukken het belang van voorzichtigheid bij de koppeling van konijnen en van een goed begrip van gedragsindicatoren om de sociale huisvesting van konijnen te verbeteren, wat uiteindelijk hun welzijn ten goede komt.

INTRODUCTION

The domestic rabbit (*Oryctolagus cuniculus*) of which the domestication process started around 1500 years ago (d'Ovidio et al., 2016), inherited its social nature from its ancestor, the European wild rabbit (Jenkins, 2001). Nevertheless, many companion rabbits are kept in solitary housing which fails to meet their social needs (Skovlund et al., 2023). In various studies, the benefits of group housing have been shown, as rabbits exhibit more species-specific behaviors including stretching and yawning, which may indicate relaxation (Whary et al., 1993; Van Damme et al., 2023a), and are generally more active (Podberscek et al., 1991; Chu et al., 2004). In solitary housed rabbits, abnormal behaviors such as fur plucking and cage biting are abundant (Gunn and Morton, 1995) and foraging behavior and life span are reduced (Schepers et al., 2023).

However, not all types of group housing are beneficial, and welfare issues might be abundant (EFSA, 2005). Opposite sex pairs are likely to show social bonding in captivity, while in same sex pairs hormonal changes starting from puberty lead to aggression (Stapleton, 2021). Neutering can mitigate aggression and other hormonal behaviors, such as spraying and nesting behavior (Harcourt-Brown, 2002). The need for surgical intervention to successfully house two rabbits of the same sex has been used as an argument by some authors that such a combination does not correspond with their natural social organization (Whary et al., 1993). Counterevidence, however, of harmonious same-sex pairs exist (DiVincenti and Rehrig, 2016).

Despite rabbits' social nature, thoughtful pairing of two or more individuals is crucial to promote harmonious cohabitation in captivity, even in opposite sex pairs (DiVincenti and Rehrig, 2017; Thurston et al., 2018). Pairing is a process of human intervention, in which individual rabbits are brought together with the goal of developing a stable social bond, often within the context of a long-term shared living environment. The first step of this pairing process (i.e. the introduction) is the initial contact period between unfamiliar rabbits during which they are gradually exposed to each other. This introduction preferably happens in a neutral environment to avoid territorial aggression and should be performed under supervision of experienced people who can interrupt in case of severe aggression (Crowell-Davis, 2007). The complete pairing process may take from a few hours to several weeks, depending on the rabbits' temperament (Mykytowycz and Hesterman, 1975; Crowell-Davis, 2007) and the need for separation and reintroduction (Crowell-Davis, 2007). A successful pairing aims at a stable social bond, which is characterized by dominant and submissive displays as well as affiliative interactions. Within a pair, one rabbit will display more dominant behavior (e.g. mounting, chasing and pushing its head under the other rabbit) while the other shows more submissive behavior such as freezing and fleeing (Thurston et al., 2018). Additionally, behavioral needs such as eating, drinking or resting are performed in close proximity while generally being tolerated by the mate, and affiliative interactions such as allogrooming are frequently shown (Thurston et al., 2018).

There is currently a lack of research on the social behavior of companion rabbits during the introduction. Most studies have focused on rabbits housed for meat (Van Damme et al., 2023a; Van Damme et al., 2023b) or laboratory rabbits (Mykytowycz and Hesterman, 1975; Held et al., 1995; Thurston et al., 2018). Consequently, little is known about how companion rabbits behave during these introductions. In this study, it is aimed to understand the social dynamics of rabbits during the introduction, focusing on opposite sex pairs. Through video observations the authors aim to explore the social behavior of companion rabbits and identify behavioral tendencies that may be associated with successful pairing.

MATERIALS AND METHODS

Ethics statement

The study was reviewed in accordance with EU Directive 2010/63 regarding the protection of experimental animals and with Ghent University policy and deemed not to require specific approval from an ethical review body. The study collected the contact details of the shelter manager (name, email address, address rabbit shelter) and videos of rabbits during the introduction. In accordance with GDPR legislation, written informed consent was obtained and data were stored securely.

Data collection

Data on the social behavior of the rabbits during the introduction was collected in collaboration with staff members of the rabbit shelter. The data consist of video recordings collected by the shelter staff and relevant background information about the rabbits. All introductions were scheduled on the initiative of the rabbit shelter and were performed following their standard protocol, which included supervised introduction of unfamiliar rabbits in a neutral environment without prior visual or olfactory introduction. Details on the environments used for the pairings can be found in Table 1.

The videos were recorded between July 2023 and December 2023 using a standardized instruction protocol modified from Van Belle et al., (2023). The participants were instructed to start the recording when the rabbits were first placed together and ended either when the shelter staff judged the interaction to be stable (i.e. no strong aggression observed and the

rabbits could be left alone) or when the rabbits had to be separated due to strong aggression (i.e. risk of injury). The participants were further instructed to avoid being recorded identifiably, avoid recording unnecessary interventions, ensure proper video quality (i.e. lighting) and to keep both rabbits completely visible (i.e. from head to tail) at any moment by holding the smartphone camera horizontally and avoiding zooming.

In total, nine introductions were recorded, involving nineteen rabbits. Eight recordings featured pairs of rabbits and one recording featured three rabbits. Two introductions were recorded by the principal investigator and seven introductions by staff members of the rabbit shelter. One of the nine introductions was excluded of the study (pairing 7) as the recording of this introduction was stopped due to practical issues not related to the behavior of the rabbits. The final study population thus consisted of 17 rabbits recorded over eight introductions. The longest recording of the introduction lasted 41.8 minutes, and the shortest 3.3 minutes, with an average of 15.4 minutes (SD = 11.72 minutes).

In addition to the videos, data about the age, sex, health and neutering status, and physical traits for individual recognition (e.g. lop ears and coat color) of the rabbits were collected from the shelter manager. Finally, it was noted whether a pairing was ultimately considered successful or not. A pairing was considered successful when the rabbits were sent with their new owner and stayed together during a period of at least three months. In Table 1, the specifications of each pairing are provided.

Observations

Behavioral observations, using an ethogram were conducted by the principal investigator with The Observer XT (Noldus, version 16), using continuous recording and focal animal sampling (consecutively per rabbit). For the study, a complete ethogram for companion rabbit behavior was developed through literature review (Lockley, 1961; Gunn and Morton, 1995; van den Bos, 1998; Troisi, 2002; Prebble et al., 2015; Pedretti et al., 2023; Van Damme et al., 2023) (Supplement Table 1 included below reference list) and supplemented with behaviors from own observations (follow, nose-nose contact, push head under other rabbit, scratch, mounting on head, turning towards other rabbit, bite, stepping over other rabbit, turn towards other rabbit and sniffing rabbit) indicated in the ethogram with an asterisk. The ethogram consisted of 54 behavioral elements categorized into six groups: general movements and postures, exploring environment, social behavior, communication, abnormal behavior and maintenance. Each behavior is described by a specific action or posture, and classified as either a states (S), where both frequency and duration of the behavior are measured, or events (E), where only the frequency is recorded.

After initial training which included screening of the collected videos, the observer tested intra-observer reliability on a subset of the collected data (1/9 introduction, 11%) for states and events separately. As the authors wanted to create detailed data on inter-rabbit interactions, the order of events/states was included in the analysis, which was conducted using the sequence/duration (states) and sequence/frequency (events) methods as incorporated in The Observer XT software. The values for Cohen's Kappa were 0.99 and 0.83, respectively, indicating excellent internal reliability (Bateson and Martin, 2021).

For the purpose of this paper, only the subset of behaviors are reported which are relevant for the social context (ethogram groups 'social behavior' and 'communication'). The behaviors extracted for analysis are displayed in Table 2. The complete ethogram can be found in the document Supplement Table 1.

Analysis

As the current study entails a pilot trial with a limited number of rabbits, the analysis is purely descriptive. Calculations were performed in Excel (version 2021). The dataset consisted of recordings for the presence (0-1), frequency (rate/min) and total duration (s) of each of the behaviors included in Table 2 as scored for the individual rabbits. For the complete dataset, calculations were made to derive the total occurrence, the average relative duration, and the average frequency of each behavior of the rabbits combined. The total occurrence (%) or occurrence in the overall population was calculated using the combined scores for presence (0-1) per rabbit. The mean relative duration was obtained by using the following formula: [total behavior duration/ (total video duration – off-screen duration)] x 100. The average frequency was obtained by using the following formula: frequency of behavior / (total video duration – off-screen duration). Furthermore, for the comparison between successful and unsuccessful pairs, the total occurrence (%), mean frequency and mean relative duration were calculated per group.

RESULTS

Study population and characteristics

The study included eight pairings, five were considered successful and three unsuccessful. A successful introduction lasted on average 15.7 minutes (SD = 15.3 min), while an unsuccessful introduction lasted 907 seconds (SD = 519.7 s). Each introduction involved one male and one female rabbit. In the trio introduction, there were two females and one male. This introduction was unsuccessful. The rabbits varied in age (median = 2 years, minimum = 0.5 years, maximum = 7 years) and were all in good health. All males were neutered, and three out of nine females were neutered.

Table 1. Description of the various areas used during the introductions in this study. The choice of these areas for each pairing was made by the manager of the rabbit shelter.

Pairing	Neutral area	Rabbits	Succes?	Duration of filming (s)
1	Outdoor pen measuring 1.5m x 1.9m on grass	A: doe of unknown age B: neutered buck of unknown age	Yes	2510s
2	Indoor space measuring 1.25m x 3.3m with a concrete floor	A: neutered doe of two years B: neutered buck of 1,5 years	No, separated at the introduction due to aggressive behavior	1505s
3	Outdoor pen measuring 1.5m x 1.9m on grass	A: neutered buck with unknown age. B: doe of 6 six years	Yes	820s
4	Indoor space measuring 1.25m x 3.3m with a concrete floor and a stool in the space	A: doe of two years B: neutered buck of seven years	No, no explanation provided by shelter staff	652s
5	Indoor space measuring 1.25m x 2.2m with a concrete floor and hay in the space	A: doe of five months B: neutered buck of two years	Yes	198s
6	Outdoor pen measuring 1.5m x 1.9m on grass	A: neutered buck of three years B: neutered doe of seven years	Yes	410s
7	Indoor space measuring 1.25m x 2.2m with a concrete floor	A: neutered doe of 1,5 years B: neutered buck of two years	Yes	108s
8	Indoor space measuring 1.25m x 2.2m with a concrete floor	A: doe of one year B: neutered buck of 2,5 years	Yes	735s
9	Indoor space measuring 1.25m x 3.3m with a concrete floor and hay in the space	A: neutered doe of one year B: neutered buck of two years C: neutered doe of two years	No, the two rabbits who where already paired injured the other rabbit	564s

Rabbit behavior during the introduction

The most observed behaviors included approaching (82.4%), sniffing (76.5%), darting (70.6%), and fleeing (64.7%) (Table 3). In contrast, behaviors with relatively low occurrence were bite (17.6%), stepping over the other rabbit (17.6%), avoidance behavior (5.8%) and retreat (5.85%) (Table 3). Behaviors with a high relative frequency were approaching (4.98 min^{-1}), fleeing (7.8 min^{-1}), and sniffing (6 min^{-1}), whereas mounting on the head (0.31 min^{-1}), retreat (0.25 min^{-1}), and scratching (0.5 min^{-1} occurred less frequently (Table 3). Behaviors with a high mean total relative duration were body contact (3.4%), freezing (2.02%), and fleeing (2.63%). Behaviors with a low mean duration were threatening (0.15%), circling (0.15%), nose-to-nose contact (0.1%), mounting on the back (0.06%), and avoidance behavior (0.004%) (Table 3).

Comparison between successful and unsuccessful introductions

Behaviors such as approaching (90%), following (50%), mounting on head (30%), freezing (30%), and sniffing the other rabbit (80%) were numerically more prevalent in rabbits from successful pairs

(Figure 1). In contrast, behaviors such as attacking (57%), body contact (44%), fighting (57%), scratching (43%), and threatening (57%) were more common in rabbits from unsuccessful pairs. When comparing the frequency of the behaviors between groups (Table 4), it can be noted that fleeing (5.6 min^{-1}) and avoidance behavior (22.8 min^{-1}) were more frequent in rabbits from successful pairs. Major differences in the duration of the behaviors scored include fleeing (3.2%), freezing (2.8%), and avoidance behavior (0.07%) (Table 5).

DISCUSSION

In this study, it was aimed to describe the behavior of companion rabbits during the introduction and to identify behaviors predictive of a successful pairing. Approaching and sniffing behaviors had a high occurrence and frequency during the introductions. Initial social contact between unfamiliar rabbits is typically initiated by these two behaviors (Bill et al., 2020; Van Damme et al., 2023b). Rabbits use sniffing as a means of establishing social relationships and pref-

Table 2. Ethogram of the social behavior of companion rabbits during an introduction between two rabbits. Behaviors marked with an asterisk (*) were added based on own observation.

Behavior	Definition
Social behavior	
Allogrooming	Licking the fur of another rabbit (Prebble et al., 2015).
Follow	The rabbit hops slowly after the other rabbit, maintaining a relaxed posture without laying its ears back.*
Approach	Slow movement towards the other rabbit, with the ears positioned either flat or upright, this may include physical contact (Van Damme et al., 2023b).
Body contact	Lying down or sitting up with body contact with another rabbit (Van Damme et al., 2023b).
Nose-contact	Touching the other rabbit's nose with one's own nose.*
Push head under other rabbit	The rabbit pushes its head under the other rabbit's head.*
Attack	Quick movement towards other rabbit, neck extended and ears flat, physical contact is made (Van Damme et al., 2023b).
Avoidance behavior	The rabbit retreats directly if approached by another rabbit, within at least one rabbit-length (Bill et al., 2020).
Threat	Quick movement towards other rabbit, ears flattened but no physical contact is made (Van Damme et al., 2023b).
Freeze	The rabbit freezes up and push his head and shoulders against the floor, ears are placed under the nose of the other rabbit. The rabbit is immobile in relation to another rabbit, or is accessed by another rabbit (Van Damme et al., 2023b).
Bite	The rabbit bites the skin of another rabbit with its teeth*.
Circle	Rabbit jumps around another rabbit (Lockley, 1961).
Scratch	The rabbit scratches the other rabbit with its front paws or kicks the other rabbit with its hind legs.*
Chasing	Aggressive (such as with ears back and growling)* running after another rabbit (Van Damme et al., 2023a; Van Damme et al., 2023b).
Mounting on head	The rabbit climbs on the other rabbit's head and makes quick thrusting movements with its hind legs with/without biting.*
Mounting	The rabbit climbs on the back of the other rabbit (Bill et al., 2020). And makes rapid thrusting movements with the hind legs (Van Damme et al., 2023a) with/without biting (Bill et al., 2020).
Stepping over other rabbit	The rabbit steps over another rabbit, making body contact.*
Darting	The rabbit hops toward the other rabbit, sometimes with an open mouth (Bill et al., 2020).
Retreat	Calmly moving away from another rabbit (Bill et al., 2020; Van Damme et al., 2023b).
Fights	Rabbit grabs the other rabbit with its teeth and/or scratches with its hind legs (Van Damme et al., 2023a; Van Damme et al., 2023b).
Flee	Running away from another rabbit (Bill et al., 2020), this may involve jumping over the attacking rabbit (Van Damme et al., 2023b).
Turn towards other rabbit	Turn to the other rabbit within one rabbit's length.*
Communication	
Sniffing rabbit	Sniffing body regions of other rabbit.*
Thump	Stamping the hind feet on the ground (Gunn and Morton, 1995).
Chin marking objects	The chin is rubbed on the floor, wall, or bars (Gunn and Morton, 1995).

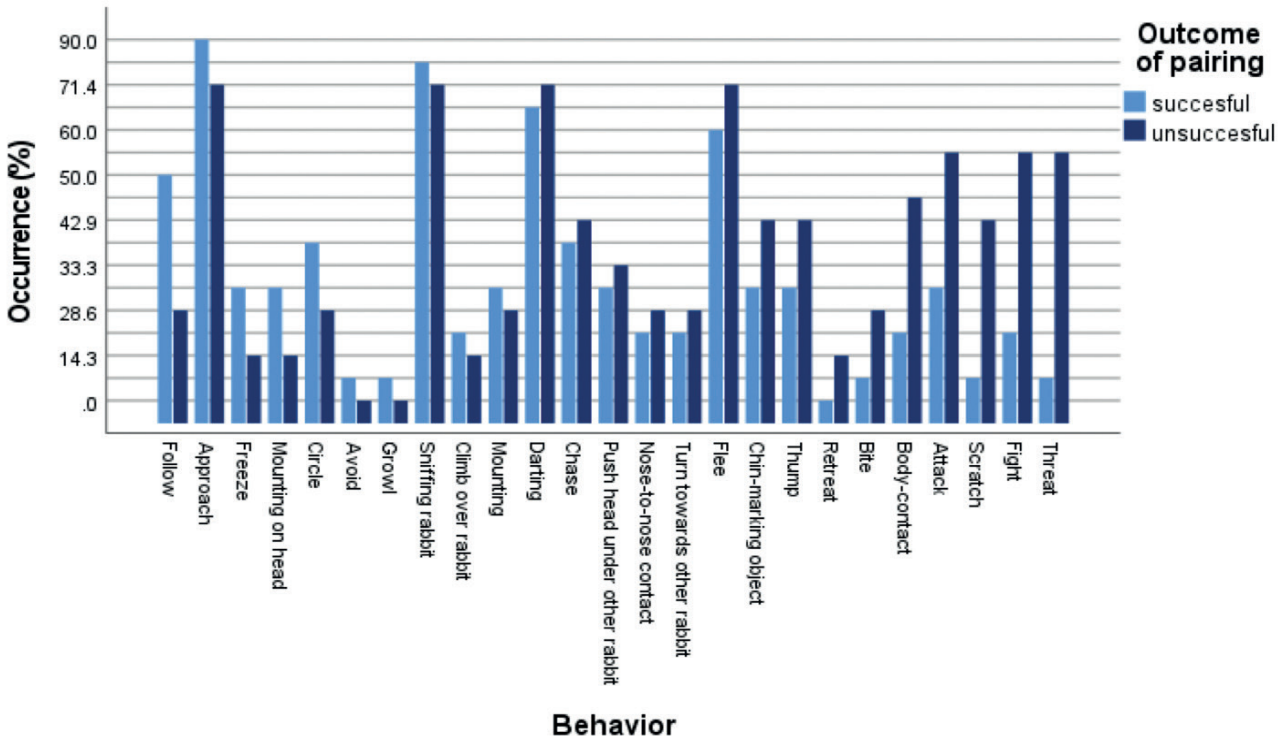

Figure 1. Occurrence (%) of behaviors performed by rabbits during the introduction compared between successful and unsuccessful pairings.

Table 3. Total occurrence(%), mean proportional frequency (min^{-1}) with standard deviation, and mean proportional duration (%) with standard deviation of the behaviors observed in rabbits during the introduction.

Behavior	Occurrence (%)	Frequency (min^{-1})	Duration (%)
Approach	82.4	4.98 ± 0.28	
Attack	41.2	1.68 ± 0.25	0.21 ± 0.0042
Avoidance behavior	5.8	1.32 ± 5.52	0.0041 ± 0.0017
Bite	17.6	0.90 ± 0.11	
Body contact	35.3	1.68 ± 0.20	3.4 ± 0.072
Chase	41.2	2.64 ± 0.34	0.36 ± 0.018
Chin marking object	35.3	1.02 ± 0.11	
Circle	35.3	0.55± 0.058	0.15 ± 0.0028
Darting	70.6	4.32 ± 0.34	0.51 ± 0.0060
Fights	35.3	2.46 ± 0.54	0.19 ± 0.0035
Flee	64.7	7.8 ± 0.58	2.63 ± 0.035
Follow	41.8	1.26 ± 0.11	0.29 ± 0.0069
Freeze	23.5	2.52 ± 0.41	2.02 ± 0.055
Mounting	29.4	1.48 ± 0.29	0.06 ± 0.035
Mounting on head	23.5	0.31 ± 0.040	1.12 ± 0.0084
Nose-to-nose contact	23.5	0.60 ± 0.24	0.1 ± 0.0023
Push head under other rabbit	35.3	0.54 ± 0.06	
Retreat	5.8	0.25 ± 0.06	
Scratch	23.5	0.50 ± 0.084	
Sniffing rabbit	76.5	6 ± 0.52	1.56 ± 0.020
Stepping over other rabbit	17.6	0.42 ± 0.096	
Threat	29.4	0.51 ± 0.40	0.15 ± 0.0045
Thump	35.3	1.56 ± 0.17	
Turn towards other rabbit	23.5	0.55 ± 0.11	

Table 4. Mean frequency (min^{-1}) and standard deviation of successful and unsuccessful pairings.

Behavior	Mean frequency successful	Mean frequency unsuccessful
Approach	3.074 ± 0.30	1.01 ± 0.14
Attack	0.39 ± 0.077	1.31 ± 0.24
Avoidance behavior	22.77 ± 7.20	0
Bite	0.54 ± 0.14	0.33 ± 0.060
Body contact	1.26 ± 0.27	0.42 ± 0.080
Chase	1.76 ± 0.41	0.92 ± 0.30
Chin marking	0.45 ± 0.10	0.42 ± 0.14
Circle	0.42 ± 0.056	0.15 ± 0.070
Darting	1.81 ± 0.39	1.66 ± 0.32
Fight	2.0082 ± 0.41	0.53 ± 0.42
Flee	5.61 ± 0.70	2.078 ± 0.42
Follow	0.91 ± 0.13	0.33 ± 0.092
Freeze	2.23 ± 0.56	0.31 ± 0.12
Mounting	0	1.49 ± 0.38
Mounting on head	0.10 ±0.031	0.21 ± 0.052
Nose contact	0.26 ± 0.055	0.34 ± 0.083
Push nose under other rabbit	0.21 ± 0.035	0.33 ± 0.09
Retreat	0	0.25 ± 0.093
Scratch	0.050 ± 0.016	0.45 ± 0.13
Sniffing other rabbit	1.54 ± 0.49	3.18 ± 0.61
Stepping over other rabbit	0.025 ± 0.0078	0.40 ± 0.15
Threat	0.027 ± 0.0085	0.48 ± 0.078
Thump	1.31 ± 0.22	0.24 ± 0.060
Turn towards other rabbit	0.28 ± 0.090	0.29 ± 0.14

erences, indicating the importance of olfactory communication during the introductions (Negretti et al., 2008; Melo and González, 2010). Furthermore, behaviors such as darting and fleeing were also commonly present, which often reflect an instinctual flight response to a perceived threat from an unknown rabbit. Fleeing helps rabbits to escape aggression (Bill et al., 2020) and is exacerbated in novel environments or during interactions with an unfamiliar conspecific. Furthermore, evasive behavior may be an indication of submission towards another rabbit (Van Damme et al., 2023b). In contrast, nose-to-nose contact, freezing, mounting on the head, and turning towards the other rabbit were less commonly observed. Although freezing was infrequent, when it occurred, it lasted for long durations. Freezing in rabbits, as well as in other species, is often seen during an acute stress-response (Salden et al., 2023). The novel environment in combination with an unfamiliar conspecific might trigger a strong stress response. Furthermore, freezing behavior also serves as a passive defense mechanism useful in a socially stressful environment (Van Damme et al., 2023b).

Behaviors were identified during the introduction that may help indicate successful pairing in rabbits. Approaching, following, mounting on the head and sniffing the other rabbit are numerically more present in rabbits, which will form a successful pair. This can be attributed not only to the inquisitive and exploratory nature of these behaviors but also to their role in establishing social hierarchies and facilitating communication (Schalken, 1976). Rabbits that follow, sniff and approach each other are showing normal interest in one another. Sniffing, as also mentioned above, serves as a form of olfactory communication, as it allows rabbits to detect odors and pheromones that convey information about identity, territorial boundaries, and social hierarchy (Schalken, 1976). This behavior helps rabbits navigate social interactions and maintain group structure. (Melo and González, 2010). Mounting is considered a dominant behavior if the purpose is not mating (Van Damme et al., 2023a). When rabbits exhibit this behavior, it may indicate the emergence of a dominance-submission relationship. In a socially stable pair of rabbits, submissive behaviors are often exhibited by one rabbit, while dominant behaviors are displayed by the other (Thurston et al., 2018). Behaviors such as attacking, fighting, scratching, threatening and body contact are more common in rabbits from unsuccessful pairs. For the majority of these behaviors (attacking, fighting, scratching and threatening), the explanation is obvious, given the agonistic nature of these behaviors (Thurston et al., 2018). Excessive aggression in rabbits can lead to potentially dangerous interactions that may cause injuries, sometimes even resulting in fatal wounds (Lockley, 1961). However, body contact (i.e., sitting or lying together) would not typically be expected in rabbits from unsuccessful pairs due to its affiliative nature. The increased occurrence of this behavior in this study could be attributed to the presence of a rabbit trio, where the two already paired rabbits searched each other's body contact during the introduction with one unfamiliar rabbit. This again high-

Table 5. Mean relative duration (%) with standard deviation of successful and unsuccessful pairings.

Behavior	Mean duration successful	Mean duration unsuccessful
Attack	0.082 ± 0.21	0.40 ± 0.59
Avoidance behavior	0.070 ± 0.22	0
Bodycontact	1.54 ± 3.24	6.05 ± 10.33
Chase	1.10 ± 1.98	1.043 ± 1.69
Circle	0.23 ± 0.35	0.036 ± 1.69
Darting	0.60 ± 0.69	0.37 ± 0.45
Fight	0.056 ± 0.12	0.38 ± 0.48
Flee	3.24 ± 4.10	1.76 ± 2.40
Follow	0.41 ± 0.88	0.12 ± 0.22
Freeze	2.78 ± 6.88	0.93 ± 2.43
Mounting	1.85 ± 4.57	0.067 ± 0.13
Mounting on head	0.44 ± 0.99	0.23 ± 0. 61
Nose-contact	0.087 ± 0.25	0, 12 ± 0.21
Sniffing other rabbit	1.59 ± 2.36	1.52 ± 1.55
Stepping over other rabbit	0.099 ± 0.29	0.012 ± 0.031
Threat	0.0009 ± 0.0028	0.36 ± 0.67

lights the stressful nature of the introduction, as this type of behavior is often observed between familiar rabbits during stressful events (Thurston et al., 2018). Fleeing, freezing, and avoidance behavior were observed for a longer duration in rabbits from successful pairs. Fleeing and avoidance behavior were also more frequent. This could be due to the conflict-avoiding nature of these behaviors.

Furthermore, the results of the present study highlight that the pursuit of social housing for rabbits is complex as three out of eight pairings in this study were unsuccessful. Cohousing incompatible individuals in a confined domestic environment with limited escape opportunities may lead to escalation of aggression with potentially (deadly) injuries as a result (Lockley, 1961). Therefore, understanding behavioral indicators during the introductions becomes even more relevant. In this study, it was aimed to facilitate this understanding by providing a concise ethogram with clearly defined descriptions and behavioral indicators of (un)successful pairing. The outcomes can assist owners or shelter staff in their evaluation of rabbit compatibility during the introduction, with the aim of achieving harmonious social housing with its numerous benefits for rabbit welfare as established in prior research (Chu et al., 2004).

To the best of the authors' knowledge, this study is the first to examine companion rabbit behavior during the introduction using behavioral observations. Given the preliminary nature of the work and limited sample size, the current study has limitations. Firstly, the shelter context and the involvement of shelter staff in video-recording has obstacles. Although based on instructions of the researchers, the recording of videos by non-researchers inherently resulted in limited control over the quality and quantity of the obtained data, and has contributed to the limited sample size in the study. Examples include that subtle behaviors (e.g. licking lips, ear positioning and freezing) may have been missed within the collected videos due to insufficient video quality (i.e. camera angle top-down, image quality), and that the variation in video length between pairings might have biased the data (i.e. an initial aggressive encounter might be underrepresented in a longer video). Furthermore, there was no follow up of the rabbits with their new owner after adoption, so details of the behavior of the rabbits in their home environment are missing. For future research, the authors suggest to expand the study towards private rabbit owners to increase sample size, which allows formal analysis of predictive behaviors or individual characteristics (e.g. breed, age) for successful pairing. Furthermore, combining a dynamic camera with the use of a high-quality fixed camera and/or on-site researchers with the aim of comparing different methodologies could contribute to the optimization of protocols for studying companion animal behavior. Lastly, behavioral observations are inherently challenging and time consuming. Future research with larger study populations may require multiple observers with adequate training, or opportunities for automated behavioral assessment may be further explored (Ipek et al., 2023). A possible direction for future studies may be exploring the effect of individual characteristics (i.e. age, breed) on pairing success. In the present study, population pairs with major age differences were present in both successful (ex. pairing 6) and unsuccessful pairings (ex. pairing 4); however, most rabbits were young (0-2years) at the time of pairing. Collecting data of a more heterogeneous sample might reveal clearer patterns.

CONCLUSION

This pilot study represents a valuable first step in exploring the social behavior of companion rabbits during pairing. It provides a thorough description of the social behaviors of companion rabbits during

introductions, highlighting differences between successful and unsuccessful rabbit pairs. Key behaviors, such as approaching, sniffing, mounting on the head and following were frequently observed behaviors in successful pairings between unfamiliar rabbits. In contrast, aggressive behaviors like attacking, fighting, and scratching were more prevalent in unsuccessful introductions. This study is a first step towards a deeper understanding of the social behavior of companion rabbits and its relation to pairing success. Future research and a better understanding of social behavior will hopefully contribute to the development of better social housing conditions and welfare of companion rabbits.

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Supplement table 1. Complete ethogram of behavioral elements in domesticated rabbits. Per behavioral element, it is indicated whether or not the behavior was scored in this study and if the behavior is a state event (S) or a point event. References to the literature are added to the definitions. Behaviors marked with * have been added by the authors based on own observations.

ETHOGRAM OF DOMESTIC RABBITS			
Behavioral element	**Description**	**Scored event**	**State/ point**
General movements and postures			
Doze	Lying or sitting with eyes slightly or half-open. Ears remain upright and responsive to environmental sounds (Gunn and Morton, 1995).	0	S
Drink	Drinking water from a water bottle (Prebble et al., 2015) or water bowl*.	0	S
Eat	Eating from a food bowl (Prebble et al., 2015), hay from a hay rack, or food from the floor*.	1	S
Hopping	Forward movement by alternating extension of front and hind legs (Prebble et al., 2015).	1	S
Hunched	The rabbit is in a squat position, appearing hunched with an arched back (Gunn and Morton, 1995).	0	S
Lie	Resting with the body on the ground, limbs stretched out or under the body (Prebble et al., 2015).	1	S
Roll	Rolling onto the back (Gunn and Morton, 1995).	1	S
Sleep	Lying or sitting with both eyes closed. Sometimes facial movements and rapid eye movements are visible. The ears usually lie flat against the back (Gunn and Morton, 1995).	0	S
Binky E	A rapid jump accompanied by secondary behaviors such as shaking/twisting the body, head swinging, or kicking with the hind legs (Gunn and Morton, 1995).	0	
Jump	Upward movement with hind legs, after which the rabbit lands back on the ground.*	0	E
Stretch	Stretching the front legs forward with the head tilted back or sitting upright and arching the back (Gunn and Morton, 1995).	0	E
Sit	Upright, sitting posture with the hindquarters and front legs on the ground (Prebble et al., 2015).	1	S

[1]addition reference Van Belle M.J.R., et al.

Exploring environment			
Chew objects	Repetitive chewing, biting, pulling, and nibbling on objects around the rabbit. For example: food bowl, water bottle, bedding, cage bars, and walls (Gunn and Morton, 1995).	0	S
Digging	Rapidly scratching the bedding with the front paws (Prebble et al., 2015).	1	S
Lick object	Licking objects in the environment*.	0	S
Jump on object	The rabbit jumps onto an object and stays there.*	1	S
Crawl under object	Rabbit crawls under an object and remains there.*	1	S
Paw scraping	Rapid scraping with front paws along the wall or floor (Prebble et al., 2015).	0	S
Sniff	Sniffing objects in the environment (Prebble et al., 2015).	1	S
Rear	Sitting on hind legs with front legs off the ground (Prebble et al., 2015).	1	S
Social behavior			
Affiliative behavior			
Allogrooming	Licking the fur of another rabbit (Prebble et al., 2015). Modifiers: head or body.	0	S
Follow	The rabbit hops slowly after the other rabbit, maintaining a relaxed posture without laying its ears back.	1	S
Approach	Slow movement towards another rabbit, with ears either flattened or upright, potentially involving physical contact (Van Damme et al., 2023b).	1	E
Body contact	Lying or sitting with body contact with another rabbit (Van Damme et al., 2023b).	1	S
Nose-to-nose contact	Touching the nose of another rabbit with own nose.*	1	S
Push head under other rabbit	The rabbit pushes its head under the head of another rabbit.*	1	E
Agonistic behavior			
Attack	Rapid movement towards another rabbit, neck extended and ears flattened, making physical contact (Van Damme et al., 2023b).	1	E
Avoidance behavior	The rabbit retreats directly if approached by another rabbit, within at least one rabbit-length (Bill et al., 2020).	1	E
Threat	Rapid movement towards another rabbit, ears flattened, but no physical contact is made (Van Damme et al., 2023b).	1	E
Freeze	The rabbit freezes or presses its head and shoulders against the floor, ears are placed under the nose of the other rabbit. The rabbit remains immobile in relation to the other rabbit, or is mounted by the other rabbit (Van Damme et al., 2023b).	1	S
Bite	The rabbit bites the skin of another rabbit with its teeth*.	1	E
Circle	Rabbit jumps around another rabbit (Lockley, 1961).	1	S
Scratch	The rabbit scratches with its front paws or kicks with its hind legs at another rabbit*.	1	E
Chasing	Aggressively (with ears flattened and growling)* running after another rabbit (Van Damme et al., 2023a; Van Damme et al., 2023b).	1	S

Mounting on head	The rabbit mounts the head of another rabbit and makes rapid thrusting movements with its hind legs, with/without biting.*	1	S
Mounting	The rabbit mounts the back of another rabbit (Bill et al., 2020), making rapid thrusting movements with the hind legs (Van Damme et al., 2023a) with/without biting (Bill et al., 2020).	1	S
Stepping over other rabbit	The rabbit steps over another rabbit, making body contact.*	1	S
Darting	The rabbit hops towards another rabbit, sometimes with an open mouth (Bill et al., 2020).	1	E
Retreat	Calmly moving away from another rabbit (Bill et al., 2020; Van Damme et al., 2023b).	1	E
Fight	Rabbit grips the other rabbit with its teeth and/or scratches with the hind legs (Van Damme et al., 2023a; Van Damme et al., 2023b).	1	S
Flee	Running away from another rabbit (Bill et al., 2020), sometimes accompanied by jumping over the attacking rabbit (Van Damme et al., 2023b).	1	S
Turn towards other rabbit	Turning towards another rabbit within one rabbit-length.*	1	E
Communication			
Chin marking rabbit	Rubbing the chin over another rabbit.*	0	E
Chin marking object	Rubbing the chin over the floor, wall, or cage bars (Gunn and Morton, 1995).	1	E
Squirt	Marking other individuals or objects with urine (Mykytowycz, 1968).	0	E
Sniffing rabbit	Sniffing various body regions of another rabbit.*	1	S
Thump	Stamping the hind feet on the ground (Gunn and Morton, 1995).	1	E
Ear positions			
Ears cannot be scored	Ears are not visible or the ears are immobile (as in lop-eared rabbits).*	1	S
Ears are down	Ears are flattened against the neck.*	1	S
Ears are neutral	Ears are upright in a neutral position*.	1	S
Ears are forward	Ears are directed forward.*	1	S
Abnormal behavior			
Yawning	The rabbit opens and closes its mouth widely (van den Bos, 1998).	0	E
Head-sway	Side-to-side movements of the head (Gunn and Morton, 1995).	0	S
Hair-chew	The rabbit repetitively passes the same tuft of fur through its mouth and chews on it, sometimes pulling out clumps of fur (Gunn and Morton, 1995).	0	S
Bar biting	Gnawing or licking the bars of the cage.*	0	S
Head in corner	The rabbit holds its head down in one of the corners of the enclosure (Gunn and Morton, 1995).	0	S
Nose-slide	The rabbit slides its nose up and down between the bars of the cage, usually standing on its hind legs and putting its front paws through the bars (Gunn and Morton, 1995).	0	S

Nose	The rabbit pushes its nose firmly against the bars without sniffing (Gunn and Morton, 1995).	0	S
Oral behavior	The rabbit brings its tongue to its nose and licks its mouth area (van den Bos, 1998).	0	E
Shake	Shaking the body, head, and/or paws (Gunn and Morton, 1995; van den Bos, 1998).	1	E
Maintenance			
Caecotrophy	The rabbit consumes feces directly from its anus (Prebble et al., 2015).	0	S
Grooming	The rabbit uses its teeth on its fur, passing the fur through its mouth while making rapid chewing motions (Gunn and Morton, 1995).	0	S
Wash	The rabbit licks its fur, particularly the flanks, face, or paws. The flanks are often cleaned with rocking head movements. The face is washed by licking one or both forepaws and rubbing them over the face. The outer ears, eyes, nose, and external ear canal are also cleaned (Gunn and Morton, 1995).	1	S
Scratch	A hind paw is used to scratch the body or head (Prebble et al., 2015).	1	S
Vocalizations			
Growl	The rabbit produces a growling sound.*	1	E
Squeak	The rabbit produces a high-pitched squeaking sound.*	0	E

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